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The policy implications of urban open space commercial vegetable farmers' willingness and ability to pay for reclaimed water for irrigation in Kumasi, Ghana

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Abstract

The acute waste management problems, coupled with the proliferation of small scale industries in many developing countries, make low quality water treatment before use inevitable in the long run. These industries have the potential to discharge effluent containing chemicals and heavy metals into the environment. The indiscriminative use of pharmaceutical products by households in many of these countries is another source of health concern. Low quality water treatment in these countries has however been hampered by the high cost of infrastructure provision and maintenance. Cost-sharing among stakeholders appears to be a promising strategy to finance and maintain the wastewater treatment infrastructure. In this study therefore, the willingness and ability of urban open space commercial vegetable farmers to pay for reclaimed water for irrigation purposes has been assessed. One hundred open space commercial vegetable

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farmers and four vegetable farmers' associations were selected and interviewed in Kumasi in Ghana using semi-structured interview schedules and interview guides respectively. The results of the study show that approximately three out of every five vegetable farmers were willing to pay for reclaimed water for irrigation. The results further show that the probability of being willing to pay by farmers who agreed that the current water they used for irrigation was harmful is approximately 5.3 times greater than that of those who did not. The analysis of the farmers' ability to pay revealed that all the farmers would be capable of paying for reclaimed water at a price of US\$0.11/m^3. This has implications for land tenure security and vegetable consumers' willingness to pay higher prices for the produce.

Keywords: Agricultural economics, Agriculture, Development

1. Introduction

The World Health Organisation's (WHO) multiple barrier interventions have been proven to be cost-effective for ensuring the safe use of low quality water for irrigation purposes (Amoah et al., 2007; Drechsel and Seidu, 2011). In this study, low quality water is used interchangeably with wastewater. It refers to one or a combination of the following: 1) domestic effluent consisting of black water (i.e. excreta, urine and associated sludge) and greywater (i.e. kitchen and bathroom wastewater), 2) effluent from commercial and institutional establishments (e.g. hospitals, restaurants and schools), 3) effluent from industries, and 4) storm water and other urban run-off (Raschid-Sally and Jayakody, 2008). The multiple barrier interventions comprise both treatment and non-treatment risks reduction options. Conventional low quality water treatment before use is however beyond the means of many developing countries (Keraita et al., 2008; Drechsel and Seidu, 2011; Qadir et al., 2010). The non-treatment risks reduction interventions are therefore the solutions to the numerous health risks associated with the use of insufficiently-treated low quality water for irrigation purposes (Keraita et al., 2014; Drechsel and Karg, 2013). These interventions include drip irrigation, simple filtration and simple sedimentation and must be combined with irrigation methods such as reduction in splashing, furrow irrigation and pathogen die-off. The multiple barrier interventions have been found to be effective for the removal of microbial contaminants in low quality water used for irrigation (Amoah et al., 2007; Drechsel and Seidu, 2011).

Subsequently, the Ministry of Food and Agriculture in Ghana has made provisions for the use of untreated low quality water in accordance with the multiple barrier interventions. This is contained in the National Irrigation Policies, Strategies and Regulatory Measures. The policy provision is "support

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best practices for the safe use of marginal quality water in accordance with World Health Organisation (WHO) Guidelines for the Safe Use of Wastewater, Excreta and Grey-water in agriculture" (Ministry of Food and Agriculture, 2011: 13). The non-treatment risks reduction interventions will continue to be relevant so long as the health risks associated with the use of low quality water for irrigation purposes continue to be pathogenic in nature (Faruqui et al., 2004; Cornish and Lawrence, 2001). These are however likely to change in the long run due to the waste management problems in many cities in Africa, as well as the illicit use of pharmaceuticals and biocide (Drechsel and Keraita, 2014:70).

The growing number of small and medium scale industries (including small scale mining and tanneries) is another source of health concern. This is because these industries have the potential to contaminate surface water bodies with chemicals and heavy metals. This is true when legislation and regulations on effluent treatment and disposal are not adequately enforced. For instance, Odoi et al. (2011) concluded that the effluent from manufacturing industries in Cape Coast in Ghana could be the source of the heavy metals (Lead [Pb] and Cadmium [Cd]) and micro-elements (Manganese [Mn], Copper [Cu] and Zinc [Zn]) they identified in the soils within the industrial area. The results of the work of Anim-Gyampo et al. (2012) also show that Mn (0.084 mg/L) and Cd (0.105 mg/L) concentrations in low quality water used for irrigation in Tamale in Ghana were higher than the WHO/FAO recommended limits of 0.050 mg/L and 0.003 mg/L respectively (Anim-Gyampo et al., 2012). Similarly, in places such as Kano in Nigeria and Ouagadougou in Burkina Faso, Chromium (Cr) has been detected in the effluent from tanneries (Binns et al., 2003; Drechsel and Keraita, 2014). The general trend, however, is that the heavy metals found in the soils are within the acceptable thresholds (Akrong et al., 2012; Anim-Gyampo et al., 2012). Nevertheless, Ryser and Sauder (2006) argue that very low levels of heavy metals in soils have the potential to hamper plant growth and reproduction. This implies that in the long run, low quality water will require conventional treatment before it is used for irrigation purposes.

Conventional low quality water treatment in developing countries has however been hampered by limited infrastructure and capital, and weak institutional capacity (Keraita et al., 2008; Drechsel and Seidu, 2011; Qadir et al., 2010). Consequently, many cities in sub Saharan Africa are unable to treat more than 10% of the low quality water generated by water users (Drechsel and Keraita, 2014). The situation is not different from other countries such as Lebanon, Iran, Mexico, Brazil, Palestine and China (Yang and Abbaspour, 2007; Madi et al., 2003; Qadir et al., 2010). With the business-as-usual scenario, Gijzen (2001) observed that it would take countries such as India, Kenya, Egypt and Bulgaria over 740 years, 1000 years, 250 years and 100 years respectively to meet the European Union effluent quality standards. These projections have

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been based on a rate of investment of 1.5% of the 2001 gross domestic product (GDP) of these countries. The implication therefore is that investments will have to be scaled-up in order to be capable of treating all the low quality water generated by the various water users. In scaling up investment therefore, users of the reclaimed water, the main ones being farmers, should be willing to and capable of paying for it for irrigation purposes.

Knowledge of farmers' willingness and ability to pay for reclaimed water in the cities in Ghana and the rest of sub Sahara Africa is limited. Available literature on the subject are based on studies conducted in semi-arid countries in the Middle East and North Africa (MENA) (Madi et al., 2003; Al-Ghuraiz and Enshassi, 2005). The climatic and socio-cultural conditions in MENA are different from SSA. This implies that the factors that affect farmers' willingness to use reclaimed water for irrigation purposes may be different from those in SSA. The need to address this knowledge gap is critical given that an understanding of farmers' willingness and ability to pay for reclaimed water could contribute to the formulation of more targeted, appropriate and effective water reuse policies towards food safety in the long term. The aim of the paper, therefore, is to assess the open space commercial vegetable farmers' willingness and ability to pay for reclaimed water for irrigation purposes in Kumasi.

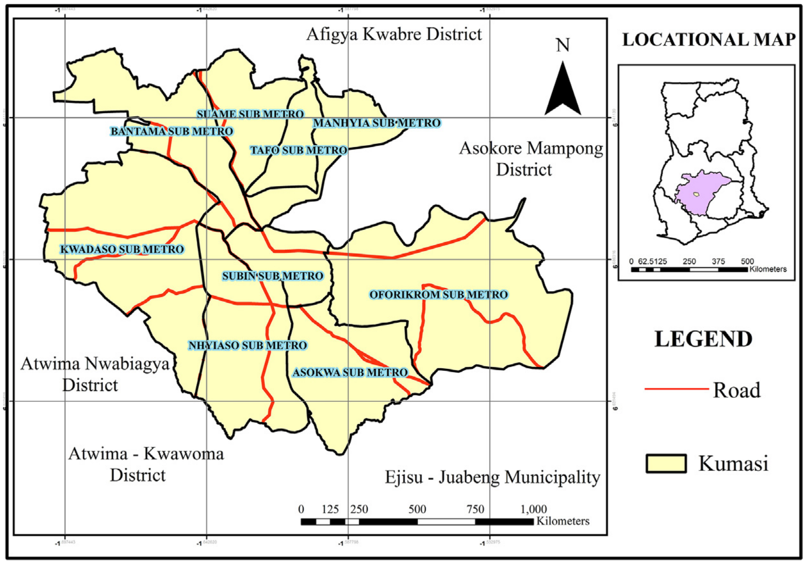

Fig. 1. Map of Kumasi Metropolitan Area showing major towns.

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1.1. Description of the study area

Kumasi (Fig. 1) is the capital of the Ashanti Region in Ghana. The city's current population is estimated to be 2.7 million people. This shows an increase of about 35% of the 2010 population of 2 million people (Ghana Statistical Service, 2012). A 2008 estimate based a daily water consumption rate of 60 L per capita and a wastewater flow of 80%, revealed that about 76,000 m^3 of low quality water was generated in the city in a day (Ackerson and Awuah, 2012). This is expected to increase to about 97,000 m^3 in a day in 2015. The city however has only five separate sewerage systems (Dahlman, 2009). These are able to serve only about 6% of the current population (Snel and Smet, 2006). The high rate of urbanisation leading to sprawl of settlements and budgetary constraints on the part of the Waste Management Department of the Local Authority, have undermined the efficiency of these low quality water treatment plants (Sinclair, 2010). Obuobie et al. (2006) had earlier reported that none of the treatment plants meets the designed effluent quality standards. A recent study of the treatment plants at the Kwame Nkrumah University of Science and Technology campus, Ahinsan Estate and Chirapatre Estates revealed that their treatment efficiency is below the Ghana Environmental Protection Agency's standards (Owusu-Ansah et al., 2015). The implication therefore is that low quality water is rarely treated before it is discharged into the environment (Keraita et al., 2010; Drechsel and Keraita, 2014).

The area under commercial vegetable farming in the city is estimated to be 59 ha in the dry season but declines to 48 ha in the rainy season (Drechsel and Keraita, 2014). The open-space vegetable farmers (who produce mainly exotic vegetables) in the city rely on the polluted surface water bodies for the supply of water for irrigation. Previous studies found that E. *coli* concentrations in this irrigation water ranged between 4.5–7.5 log colony forming units (CFU) per 100 ml (Amoah et al., 2007). This exceeded the WHO's recommended level of 3 log CFU per 100 ml (Keraita et al., 2013). Helminth eggs concentrations (particularly, *Ascaris lumbricoides)* also ranged from 2–3 eggs per litre; and exceeded the WHO's threshold of less than one viable helminth egg count per litre (Keraita et al., 2013).

Available data from 1961 to 2012 obtained from the Ghana Meteorological Department (G-MET) show that the mean amount of rainfall recorded in Kumasi is 1383 mm; which is recorded for an average of 126 days in a year. The number of annual rainfall days appears to be declining (Fig. 2). This could imply that the farmers would continue to depend on the polluted water bodies, which are known to be reliable, for water for irrigation purposes. As reported in previous studies, the use of low quality water for irrigation purposes has enabled the farmers to cultivate vegetables all-year-round (Abaidoo et al., 2009; Amoah

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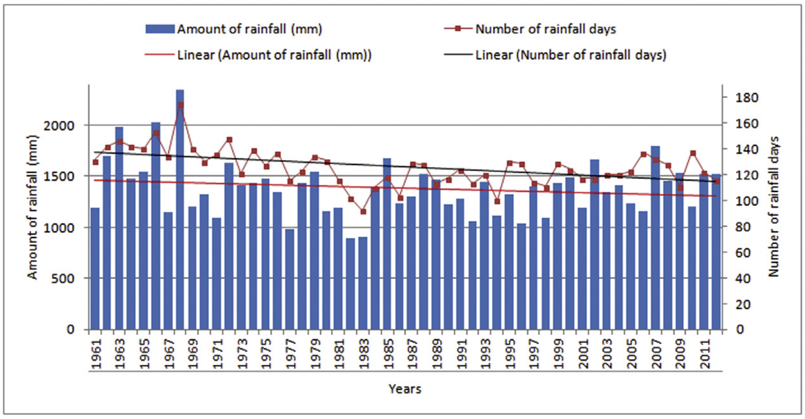

Fig. 2. Total rainfall and rain days between 1961 and 2012.

et al., 2011; Drechsel et al., 2006; Rojas-Valencia et al., 2011). Their incomes are therefore higher than the per capita income in Ghana (Drechsel et al., 2006) and twice that of farmers in rural areas (Drechsel and Keraita, 2014). Nevertheless, there are health concerns about the use of untreated low quality water for irrigation purposes. For instance, it has been estimated that about 12,000 Disability-Adjusted Life Years (DALY) are lost in five major cities in Ghana due to the consumption of contaminated vegetables (Seidu et al., 2008). Several studies have identified that the vegetables produced with untreated low quality water in Kumasi contain higher concentrations of microbial pathogens. For instance, more than 50% of the lettuce Ackerson and Awuah (2012) sampled from a number of open space vegetable farms in Kumasi contained faecal coliform counts of more than 3.7 log 100 CFU·g^{-1} fresh weight and mean helminth egg population ranging from 6 to 19 eggs/100 g wet weight. These results are similar to those of previous studies (Amoah et al., 2005; Amoah et al., 2007). The farmers in the city have failed to adopt the WHO's non-treatment risks reduction interventions. The institutions responsible for food safety in the city (such as the Metropolitan Agricultural Development Unit and Environmental Health Directorate) also ascribe to water quality standards (Amponsah et al., 2015). This implies that there is the need to adopt strategies to overcome the prohibitive cost of providing wastewater infrastructure in order to reclaim water for irrigation purposes in Kumasi.

2. Methods

2.1. Research design

The study was designed as a cross sectional survey. In this regard, semi-structured interviews were held with 100 open space commercial vegetable farmers in the Kumasi Metropolis in Ghana. The responses obtained from these semi-structured

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interviews were supplemented with data obtained from four different focus group discussions with four vegetable farmers' associations.

2.2. Sampling strategy

The literature provided different accounts of the number of open space commercial vegetable farmers in Kumasi prior to the commencement of this study (i.e. January, 2014). For example, (Drechsel et al., 2010) had observed that more than 300 open space commercial vegetable farmers were operating within the city while Darkey et al. (2014) claimed the number to be 408. Due to this, a head count of the commercial vegetable farmers was undertaken at 15 major vegetable producing sites. Two hundred and forty-nine open space commercial vegetable farm owners were identified (Table 1). The difference between this and the number reported by Drechsel and Keraita (2014) might have resulted from the variations in the boundaries used in the two studies. While the present study did not extend beyond Ayigya, Drechsel and Keraita's

Table 1. Location of sampled vegetable farmers according to the major vegetable producing sites in Kumasi.

Location	Population	Sample size
Gyinyase:		
Farmwell Organic Vegetable farmers	12	5
Karikari farms: Progressive Vegetable Growers' Association	20	8
Peace and Love Vegetable Growers' Association	15	6
Ayeduase New site	34	14
Emena:		
Hospital	14	6
Township	17	7
KNUST:		
College of Engineering: Frafra Vegetable Farmers' Association	18	>7
Business School	15	6
Hall Six and Gaza	35	14
Ayigya-Tech-Kentinkrono	7	2
University of Education, Kumasi Campus	20	8
Apemso	29	12
Presbyterian Girls Senior School	6	2
Sir Max – Ahodwo	3	1
Ayigya (affordable housing)	4	2
Total	249	100

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(2014) included Asokore-Mampong and Sawaba New site. These settlements are no longer part of the city's administrative area. One hundred vegetable farmers were then chosen from the list of 249 open space commercial vegetable farmers for this study. The proportional allocation method (Eq. (1)) adopted from Kothari (2004) was used to distribute the sample equitably among the 15 vegetable producing sites.

$$n_h = \left(\frac{N_h}{N}\right) \times n \tag{1}$$

where n_h is the sample size for site h. N_h is the population of vegetable farm owners in site h. N is total number of farmer owners in the 15 sites. n is total sample size (i.e. 100).

The final selection of farmers at each location was done by: 1) writing their names on pieces of paper, 2) dropping the papers in a box, 3) shuffling thoroughly, and 4) hand-picking them until the required numbers were obtained.

2.3. Data collection tools and process

2.3.1. Design of the tools for data collection

Three data collection tools were used in this study. They were: 1) semi-structured interview schedules, 2) interview guides and 3) observation checklist.

2.3.1.1. Design of semi-structured interview schedules

These were organised to facilitate the collection of data on the following: 1) farmers' demographic and socioeconomic characteristics, 2) farm characteristics (including types of vegetables cultivated, farm size, annual outputs, sources and volume of water used for irrigation in a year, land tenure arrangements and revenue and expenditure balance), 3) willingness to pay for reclaimed water, and 4) ability to pay for reclaimed water. The semi-structured interview schedules were administered to the selected open space commercial vegetable farmers.

A pre-test of the semi-structured interview schedules was done with 20 vegetable farmers. It was intended to assess their accuracy and completeness as well as have an overview of how the farmers would react to the questions during the interview. It was also intended to have an idea of the time needed to complete an interview. The results and the farmers who were covered in the pre-test were not included in the final study.

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2.3.1.2. Design of interview guides and observation checklist

The interview guides were structured to collect data on the vegetable farmers' associations' willingness to pay for reclaimed water for irrigation. It was also organised to gather data on the conditions under which these associations would be willing to use reclaimed water for irrigation.

The observation checklist was designed to gather data on: 1) the capacity of the watering cans used for irrigation, 2) the number of cans of water each farmer used during irrigation, 3) the types of vegetables each farmer cultivated and 4) the number of vegetable beds each farmer owned.

2.3.2. Process of data collection

2.3.2.1. Conduct of the semi-structured interviews

Face-to-face interviews, lasting for approximately 30 min, were used to gather the required data from each chosen vegetable farmer. The same questions were read out (and explained) to each of them. Their wording and explanation the same for each farmer. The responses from each farmer were then matched with the pre-coded responses in the semi-structured interview schedule.

The rights of each open space commercial vegetable farmer were respected in this study. Each of them was briefed about the purpose of the study. Their consents were sought before the interview commenced. Each farmer was told that s/he reserved the right to decline to be part of the study or redraw his/her consent even after the interview had begun, and that doing so will not attract any penalties or loss of benefits that s/he would otherwise be entitled to.

The contingent valuation method, which proceeds by simply asking respondents the highest amount they are willing to pay for a non-economic good, could have been adopted to determine the farmers' willingness to pay for reclaimed water. The relevance of this approach for policy decisions has however been brought to question since the responses are based on stated rather than observed preferences. The amount respondents are willing to pay, determined from this approach, is often low and unrealistic (Madi et al., 2003). To address this limitation, the "contingent valuation method with dichotomous choice responses" was used in this study. The bid prices used in this study have been based on the tariff structure of the Ghana Water Company Limited as at May, 2014. They were : 1) US\$0.46/m^3 (equivalent to 0.7 US Cents [or 2 Ghana Pesewas] per 15-litre watering can), 2) US\$0.46/m^3 within the first 20 m^3 and US\$0.69/m^3 (equivalent to 1 US Cent [or 3 Ghana Pesewas] per 15-litre watering can) for any additional volume of water used, 3) US\$0.69/m^3, 4) US\$0.99/m^3 (equivalent to 1.5 US Cent [4.5 Pesewas] per 15-litre watering can) and more than US\$0.99/m^3. The limitation for using these bid prices is that the price of reclaimed water is often lower than that of treated

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freshwater. This limitation has however been addressed through an analysis of the farmers' ability to pay.

Prior to presenting the questions on willingness to pay, each vegetable farmer was informed that the health risks associated with the use of untreated low quality water could result in total ban on its use for irrigation purposes. At the same time, the economic water scarcity/vulnerability challenge in Ghana (UNESCO (World Water Assessment Programme), 2009; WWAP (United Nations World Water Assessment Programme), 2015) could result in the unavailability of treated freshwater for irrigation. Reclaimed water could then be permitted as an alternative source of water for irrigation purposes. Its supply would be reliable due to urbanisation (Scott et al., 2004) provided local authorities have the required funds for low quality water reclamation. This prelude was necessary because it was anticipated that without that none of the farmers would be willing to pay for reclaimed water for irrigation purposes.

Each vegetable farmer was then asked to indicate his/her willingness to pay. The first question each of them was asked was “will you be willing to pay for reclaimed water for irrigation” (no or yes)? They were then requested to give reasons for their responses. A farmer who expressed his/her willingness to pay was then asked the following specific questions:

i. will you be willing to pay for reclaimed water at US\$0.46/m^3 (equivalent to 2 Ghana Pesewas per 15 litre watering can) (yes or no)?
ii. if yes to 'i', will you be willing to pay if the price is increased to US\$0.46/m^3 for a volume (m^3) within the first 20 m^3 and then US\$0.69/m^3 (equivalent to 3 Ghana Pesewas per 15 litre watering can) for the remaining quantity of reclaimed water used (yes or no)?
iii. if yes to 'ii', will you be willing to pay if the price is increased to US\$0.69/m^3 (yes or no)?
iv. if yes to 'iii', will you be willing to pay if the price is increased to US\$0.99/m^3 (equivalent to 4.5 Ghana Pesewas per 15 litre watering can) (yes or no)?
v. if yes to 'iv', will you be willing to pay at a price which is more than US\$0.99/m^3 (yes or no)?
vi. if you are not willing to pay any of the bid prices, what is the highest amount you are willing to pay?

2.3.2.2. Conduct of the focus group discussions

The associations that were covered in the focus group discussions were the: Farmwell Organic Vegetable Farmers’ Association, Peace and Love Vegetable

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Farmers' Association, Frafra Vegetable Farmers' Association and Progressive Vegetable Farmers' Association. Following the work of Manoranjitham and Jacob (2007), 10 members each of the four associations were selected for separate group discussions. Three of these were purposively selected from the associations' leadership. They were the:chairperson, secretary and treasurer. The other seven participants were only members of the associations. They were selected by: 1) writing their names on pieces of paper, 2) dropping the papers in a box, 3) shuffling thoroughly, and 4) hand-picking them until the required numbers were obtained.

The participants were asked to respond to the questions in the interview guides. Their responses were tape-recorded (with their permission) and hand-written. These were played back to them for confirmation after the discussions with each group had ended.

2.3.2.3. Conduct of the observations

The questions in the observation checklist were answered by the authors by observing the farmers as they went about their activities. This was interspersed with interviews that were meant to minimise the effects of the authors' biases on the results of the observation. Each observation lasted between 15 and 20 min. The results were used to validate the responses obtained from the semi-structured interviews.

2.4. Data Analyses

The data were analysed to test if:

i. the probability of a farmer being willing to pay for reclaimed water could be influenced significantly by a number of explanatory variables obtained from their socio-economic and demographic characteristics (Table 2);
ii. urban open space commercial vegetable farmers were capable of paying for reclaimed water for irrigation.

2.4.1. Willingness to pay

Willingness to pay was defined as the preparedness (yes/no) of a farmer to pay for reclaimed water for irrigation. "Yes" response to the initial question in section 2.3.2.1 was interpreted as being willing to pay. The bid prices were then presented to every farmer who expressed his/her willingness to pay for reclaimed water. This was to ascertain the highest possible amount s/he was willing to pay.

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Table 2. Description of the explanatory variables used for the explanation of the urban open space commercial vegetable farmers' willingness to pay for reclaimed water.

S No.	Variables	Acronym	Description of the variable	Type of variable
1.	Age of the farmers (years)	Age	This refers to the life years of a farmer after birth (in years). It was hypothesised that a farmer's age does not significantly explain his/her willingness to pay for reclaimed water. This was rejected at $p \leq 0.05$.	Continuous
2.	Number of persons per household	Household size	This refers to the number of people constituting a farmer's household. A household has been defined as the number of people who share the same housekeeping arrangements. It was hypothesised that the size of a farmers' household does not significantly explain his/her willingness to pay for reclaimed water. This was rejected at $p \leq 0.05$.	Continuous
3.	Television watching habit (in hours per day)	TV Habit	TV habit refers to the number of hours a farmer devoted to watching television programmes in a day. Given that risks reduction measures could be aired on Ghanaian airwaves, it has been hypothesised that TV watching significantly explains farmers' willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Continuous
4.	Radio listening (in hours per day)	Radio Habit	This refers to the number of hours a farmer spent listening to radio programmes in a day. It was hypothesised that farmers' radio listening habit significantly explains their willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Continuous
5.	Newspaper reading habit (in hours per day)	Newspaper Habit	Newspaper habit refers to the number of hours a farmer devoted to reading newspapers in a day. It was hypothesised that farmers' newspaper reading habit significantly explains their willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Continuous
6.	Number of years of farming (years)	Experience	Experience refers to the number of years a farmer has been engaged in vegetable production in the city or elsewhere. Farmers who have been engaged in farming for more years may be willing to pay to sustain their economic activity. It was hypothesised therefore that 'experience' significantly explains the farmers willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Continuous
7.	Net revenue per capita (US$)	Per capita revenue	Per capita revenue has been used as a measure of the wealth derived from vegetable farming. It was hypothesised that per capita revenue is a significant factor which explains the farmers' willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Continuous

(*Continued*)

Table 2. (Continued)

S No.	Variables	Acronym	Description of the variable	Type of variable
8.	Annual net-revenue	Net revenue	The net revenue is the difference between the annual gross revenue and expenditure for each farmer. It was hypothesised that a farmer's net revenue significantly explains his/her willingness to pay for reclaimed water for irrigation. This was accepted at $p \leq 0.05$.	Continuous
9.	Farm size determined by the number of beds (number)	Beds	The number of beds a farmer owned was used as a proxy to estimate his/her farm size. It was hypothesised that the farm size is a significant factor which explains farmers' willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Continuous
10.	Sex of the farmers	Sex	Sex refers to the biological make (either male or female) of a vegetable farmer. It was hypothesised that farmer's sex is not a factor which explains their willingness to pay for reclaimed water. This was rejected at $p \leq 0.05$.	Categorical (dichotomous)
11.	Highest educational attainment	Education	This was defined as the highest level of formal education a farmer attained prior to starting the economic activity. It was anticipated that farmers who have higher educational attainments would be know the health benefits of using reclaimed water instead of untreated low quality water. It was therefore hypothesised that formal educational level is a significant factors which explains farmers' willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Categorical (ordinal)
12.	Perception about the quality of water used for irrigation	Perception	This refers to farmers who agreed that the water used for irrigation is harmful to the health of the farmers and consumers. It was hypothesised that farmers' perception is a significant explanatory factors for their willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Categorical (dichotomous)
13.	Land tenure security	Land tenure	This refers to the ownership of the land used for vegetable farming. Farmers who have secure land tenure (even in de facto terms) were expected to be willing to pay for reclaimed water. The hypothesis therefore was that land tenure security significantly explains farmers' willingness to pay for reclaimed water. This was accepted at $p \leq 0.05$.	Categorical (dichotomous)
14.	Source of water for irrigation	Irrigation water	The types of water used for irrigation have been categorised into two namely: 1) contaminated and 2) uncontaminated. It was hypothesised that farmers source of irrigation water is a significant predictor of their willingness to pay for reclaimed water for irrigation. This was accepted at $p \leq 0.05$.	Categorical (dichotomous)

(Continued)

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Table 2. (*Continued*)

S No.	Variables	Acronym	Description of the variable	Type of variable
15.	Consumption of part of the vegetables at the household level	Consumption	The vegetable farmers who consumed some of the vegetables they produced were thought to be willing to pay for reclaimed water to sustain their source of food and protect their health. It was therefore hypothesised that 'consumption' is a significant factors which explains the farmers' willingness to pay for reclaimed water. The hypothesis was accepted at $p \leq 0.05$.	Categorical (dichotomous)
16.	Participation in farm-based multiple barrier interventions field trials / workshops	Participation	This refers to farmers who have ever participated in risks reduction field trials or workshops. It was hypothesised that participation in field trials or workshops on the health risks associated with untreated low quality water reuse for irrigation is a significant explanatory factors farmers' willingness to pay for reclaimed water. The hypothesis was accepted at $p \leq 0.05$.	Categorical (dichotomous)
17.	Membership of farmers association	Membership	It has been hypothesised that membership of vegetable farmers' association is not a significant predictor of farmers' willingness to pay for reclaimed water. This was rejected at $p \leq 0.05$.	Categorical (dichotomous)
18.	Access to agricultural extension service	Agric Extension	It was hypothesised that access to agricultural extension services is a significant explanatory factor for farmers' willingness to pay for reclaimed water for irrigation. The hypothesis was accepted at $p \leq 0.05$.	Categorical (dichotomous)
19.	Ability to pay US\$0.46/m^3	ATP@US \$0.46/m^3	It was hypothesised that a farmers' ability to pay for reclaimed (based on the 5% threshold) at US\$0.46/m^3 is a significant explanatory factor his/her willingness to pay. The hypothesis was accepted at $p \leq 0.05$.	Categorical (dichotomous)
20.	Ability to pay US\$0.69/m^3	ATP@US \$0.69/m^3	It was hypothesised that a farmers' ability to pay for reclaimed (based on the 5% threshold) at US\$0.69/m^3 is significantly explains his/her willingness to pay. The hypothesis was accepted at $p \leq 0.05$.	Categorical (dichotomous)
21.	Ability to pay US\$0.99/m^3	ATP@US \$0.99/m^3	It was hypothesised that a farmers' ability to pay for reclaimed (based on the 5% threshold) at US\$0.99/m^3 significantly explains their willingness to pay. The hypothesis was accepted at $p \leq 0.05$.	Categorical (dichotomous)
22.	Location of farm according to sub metropolitan area	Location	The vegetable producing sites were categorised into three groups based on the sub-metropolitan areas they were located. It was hypothesised that farmers' location in the city does not significantly explain their willingness to pay for reclaimed water. The hypothesis was rejected at $p \leq 0.05$.	Categorical (ordinal)

The Fisher's Exact test was used to scan for potentially significant explanatory variables from a list of 22 explanatory variables (Table 2). To run the test, the continuous variables in the list were categorised based on national statistics (Table 3). The variables with p-values of ≤ 0.25 after the Fisher's test were deemed to have the potential of significantly influencing the farmers' willingness to pay. These were then analysed in a multivariable logistic regression model using the backward elimination method. It was meant to control for potential confounding effects among the variables. After the multivariable analyses, the variables that had p-values ≤ 0.05 were deemed to have significant effects on the farmers' willingness to pay for reclaimed water. They were then subjected to multi-collinearity test. A variance inflation factor (VIF) value of 3 or more implied the presence of collinearity among the explanatory variables. The odd ratio (OR) and relative risk (RR) for each explanatory variable, which significantly explained the farmers' willingness to pay for reclaimed water, was calculated using EPI Info 7 (Centres for Diseases Control and Prevention).

To validate the results, all the 22 explanatory variables (both continuous and categorical) were analysed together in a multi-variable logistic regression. Variables with p-values ≤ 0.05 after this analysis were deemed to have significant effects on willingness to pay. These variables were subjected to multi-collinearity test (as explained earlier in the text).

The 22 explanatory variables were also analysed using ordinal logistic regression with proportional odds to determine the amount the farmers were willing to pay. The outcome variable was "amount farmers were willing to pay" with the following categories: 1) no (i.e. not willing to pay any amount), 2) US\$0.46/m^3, 3) US\$0.46/m^3 for the first 20 m^3 and US\$0.69/m^3 for the remaining quantity of water used, 4) US\$\$0.69/m^3 and 5) 0.99/m^3. Variables with p-values ≤ 0.05, after the analysis, were deemed to significantly explain the probability that a farmer was willing to pay higher amounts for reclaimed water. Prior to performing this analysis, the variables were subjected to multi-collinearity test. Those with VIF of 3 or more were deemed to have multi-collinearity issues. As the results will show, one of such variables was eliminated from the model.The final model was tested for proportional odds (significant if p-value > 0.05) and Goodness-of-Fit (significant if p-value > 0.05).

2.4.2. *Ability to pay for reclaimed water*

Farmers' ability to pay was assessed by following these sequential steps:
1) estimating the volume (cubic metres) and quantifying the value (US\$) of water used for irrigation per annum, 2) estimating the annual gross revenue obtained from vegetable farming, and 3) applying the threshold/benchmark (i.e. the

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Table 3. Categorisation of the continuous variables using national statistics and for use in a binary logistic regression analysis.

Variables	**Description of the variable**	**Type of variable**
		Categorical
Age	Farmer's age in years	Low = less than 30 years High = 30 years and above
Household size	Number of people constituting his/her household	Small = less than 4 persons Large = 4 or more persons
Television	Number of hours the farmer watches television in a day	Weak = less than 2 hours a day Strong = 2 or more hours a day
Radio	Number of hours the farmer listen to radio in a day	Weak = less than 3 hours a day Strong = 3 or more hours a day
Newspaper	Number of hours the farmer reads newspapers in a day	Weak = less than 1 hour a day Strong = 1 or more hours a day
Experience	The number of years the farmers has been cultivating vegetables in the city.	Low = less than 2 years High = 2 or more years
Annual net revenue (income level per household)	The difference between gross revenue and gross expenditure	Low = less than US$4,280 per annum High = US$4,280 or more per annum
Income per capita	The net revenue divided by the household size	Low = Less than US$735/annum High = More than US$735/annum
Number of beds	Number of vegetable bed owned by a farmer	Low = less than 30 beds High = 30 or more beds

expenditure on irrigation water at each bid price should not exceed 5% of the gross revenue) for measuring ability to pay (Al-Ghuraiz and Enshassi, 2005).

2.4.2.1. Estimation of the volume of water used for irrigation per annum

The volume of water used for irrigation (VW) was calculated from Eq. (2).

$$VW = C \times NC \times NID \tag{2}$$

where *VW* is the Volume (m^3) of Water used for irrigation per annum. *C* is the Capacity of the watering can (mainly 15 litres). *NC* is the Number of Cans of water used for irrigation in a day. *NID* is the Number of Irrigation Days in a year (assumed to be 239 non-rainfall days].

Eq. (3) was then used to estimate the expenditure each open space commercial vegetable farmer would incur on reclaimed water at the various bid prices.

$$Exp = VW \times BP \tag{3}$$

Where *Exp* is the total Expenditure (US$) to be incurred on reclaimed water. *VW* (m^3) is the Volume of Water used for irrigation per annum. *BP* is the Bid Price (ranging from US$0.46, through US$0.69/m^3 to 0.99 per m^3).

2.4.2.2. Estimation of annual gross revenue

Eq. (4) was used to estimate each farmer's annual gross revenue.

$$GR = P_{fg} \times O_{i-k} \tag{4}$$

where *GR* is the Gross Revenue (US$) per farmer per year. P_{fg} is the Farm-gate Price (US$) of each type of vegetable cultivated by the farmers. O_{i-k} is the Total Output of each type of vegetable i - k produced by the farmer.

2.4.2.3. Assessment of farmers' ability to pay for reclaimed water

Ability to pay was defined as the maximum share of annual gross revenue that each farmer would be able to spend on reclaimed water without compromising his/her ability to afford other essential goods and services required to sustain his/her farm and family. A benchmark of 5% of total annual gross revenue was used (see: Al-Ghuraiz and Enshassi, 2005). This means that a farmer is deemed to be capable of paying for reclaimed water if the total expenditure on irrigation water based on the various prices in a year would not exceed 5% of his/her gross revenue for that year. This is expressed as:

$$P_w \times VW \leq 0.05 \times GR \tag{5}$$

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where VW is the Volume (m^3) of Water used for irrigation per annum. P_w is the Price per cubic metre. GR is the annual Gross Revenue (US$) of a farmer. *0.05* is the threshold (ranging from US$0.46, through US$0.69/m^3 to 0.99 per m^3).

2.4.3. Estimation of net-revenue

The items that were considered for the estimation of the total cost of production were adopted from the work of Nemes (2009) and shown in Table 4.

$$NR = GR - (TFC + TVC) \tag{6}$$

where GR is the annual Gross Revenue (U$) of a farmer. TFC is the Total Fixed Cost (US$). TVR is the Total Variable Cost (US$).

3. Results and discussion

3.1. Description of the vegetable farmers

Out of the 100 vegetable farmers that were contacted, 98 were willing to be part of the study. Their demographic and socio-economic (Table 5 and Table 6) were similar to those of earlier studies (Owusu et al., 2012; Drechsel et al., 2006). They have been engaged in vegetable farming for approximately 10 years. Most of them have the habit of listening to radio programmes while working on the farms in the day time and watching television programmes after work. These programmes were telecast in vernacular and therefore served as sources of information and entertainment. In contrast to the results of previous studies (Amoah et al., 2007; Drechsel and Keraita, 2014), most of these farmers (at least nine out of every 10) consumed part of the produce although their business was not to produce the crops for subsistence. Rice has become a major food staple for these urban vegetable farmers. Theyused some of the vegetables to prepare sauces and sometimes salad to supplement it.

Only three out of every 10 vegetable farmers were members of farmers' associations (Table 6). This could explain their limited access (48%) to agricultural extension services. This is because the vegetable farmers' associations have often been used by the Agricultural Extension Agents to mobilise the farmers for interaction. More than 71% of them had never participated in field trials or workshops organised to create awareness of the farm-based health risks reduction interventions.

3.2. Description of the farms

Lettuce *(lactuca sativa)*, spring onions *(allium cepa)* and cabbage *(brassica oleracea)* were the dominant vegetables cultivated by the open space commercial vegetable farmers covered in the current study (Table 7). Amoah et al. (2007)

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Table 4. Items considered in the estimation of the annual total cost of vegetable production. Source: Adapted from Nemes (2009).

Fixed Cost (US$)	Variable Cost (US$)
Rental of land spread over the number of years the agreement covers	Ploughing and tillage
Land charges and administrative costs spread evenly to cover the number of years the land has been acquired for	Seeds and transplants
Servicing farm-related loans spread over the number of years the loan is expected to be repaid	Fertilisers, manure and mulch
Replacement values of machines including depreciation, interest and insurance spread over the lifespan.	Pesticides and herbicides,
	Energy (electricity and fuel)
	Labour (regular and seasonal hired labour)
	Machine repair and maintenance
	Renting equipment
	Cold storage
	Transport
	Variable irrigation expenses
	Other materials (e.g. packing containers)
	Record keeping and certification costs

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Table 5. Characterising the urban vegetable farmers using the continuous variables.

	Results				
Variables	**Minimum**	**25thpercentile**	**50thpercentile**	**75thpercentile**	**Maximum**
1. Age [life years after birth]	24	30	35	43	76
2. TV habit [hours/day]	1	2	3	3	4
3. Household size [number/household]	1	2	4	5	7
4. Radio habit [hours/day]	2	3	4	5	8
5. Newspaper habit [hours/day]	0	0	0	0	0
6. Experience [years]	1	8	10	14	22
7. Net revenue [US$]	427	1,607	2,784	6,924	25,051
8. Per capita revenue [US$/annum]	93	482	1,000	2,040	17,482
9. Beds	15	22	33	60	200

attribute this dominance to the high demand for them by the booming fast-food enterprises in the cities in Ghana. Drechsel and Keraita (2014) also found that the lack of cold storage and inefficient transportation systems that connect the rural areas to urban areas in Ghana have made it risky to cultivate these perishable vegetables in the rural areas.

Table 6. Characterising the urban vegetable farmers using categorical variables.

Variable	**Results**		
1. Sex [%]	Male, 90	Female, 10	
2. Education [%]	None, 31	Basic, 61	Secondary and above, 9
3. Perception [%]	There are no health risks, 13; There are health risks, 87		
4. Land tenure [%]	Secure, 9	Insecure, 91	
5. Irrigation water [%]	Contaminated, 100: [stream=22, shallow wells=78]		
	Uncontaminated, 0		
6. Consumption [%]	No, 4	Yes, 96	
7. Participation [%]	No, 71	Yes, 29	
8. Membership [%]	No, 70	Yes, 30	
9. Agric. extension [%]	No, 52	Yes, 48	
10. ATP@US$0.46/$m^3$	No, 63	Yes, 37	
11. ATP@ US$0.69/$m^3$	No, 88	Yes, 12	
12. ATP@ US$0.99/$m^3$	No, 6	Yes, 94	
13. Location	South-western (Oforikrom Sub Metro), 75%		
	Southern-most (Asokwa and Nhyiaeso Sub Metros), 17%		
	North-western (Kwadaso Sub Metro), 8		

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Table 7. Typologies of vegetables cultivated by the farmers.

Vegetable	Number = 98	Percentage
Cabbage (*Brassica oleracea*)	22	23
Lettuce (*Lactuca sativa*)	68	69
Spring onion (*Allium cepa*)	67	68
Carrots	1	1
Green pepper	1	1

Land tenure insecurity has been a challenge to the sustenance of the open space commercial vegetable farms covered in the present study. Majority (approximately 70%) of the farmers were occupying public/government lands. Twelve percent were free-occupants while 6% each were renting and taking care (care-takers) of other people's lands. Only 3% owned their lands. Agricultural land use's inability to compete for space against residential, industrial and commercial land uses in the cities [as exemplified in the bid-rent theory] (Alonso, 1960; Erickson et al., 2011) could be a plausible explanation for the land tenure security challenges. For instance, a plot size averaging 0.13 acres (equivalent to 520 square metres) in Kumasi was leased between US $7,500 (in the periphery) and US$125,000 (in the city centre) in 2011 (Land Valuation Division, 2011 cited in Hammond, 2011). Amponsah et al. (2015) demonstrate that an urban commercial vegetable farmer would need not less than 18 years to acquire a plot of this size at the periphery if s/he is to save his/her entire income from farming. City authorities have also failed to make provisions for agriculture in the city's land use plans (Fig. 3) despite the support policies (such as the Food and Agricultural Sector Development policy 2 and Urban Policy) give to crop farming in the cities in Ghana. Consequently, vegetable farming in the city has been confined to marginal lands along surface water bodies (Fig. 4). These lands have been zoned as open spaces because they are deemed unsuitable for residential, commercial and industrial development in their present state.

3.3. Assessment of the open space urban commercial vegetable farmers' willingness to pay for reclaimed water for irrigation

3.3.1. Results of the cross-sectional survey

The results show that three out of every five open space commercial vegetable farmers covered in this study were willing to pay for reclaimed water for irrigation. Almost 30% of these farmers were willing to pay the highest price of US$0.99/m^3 (Fig. 5). The reasons for their willingness to pay include: 1) to

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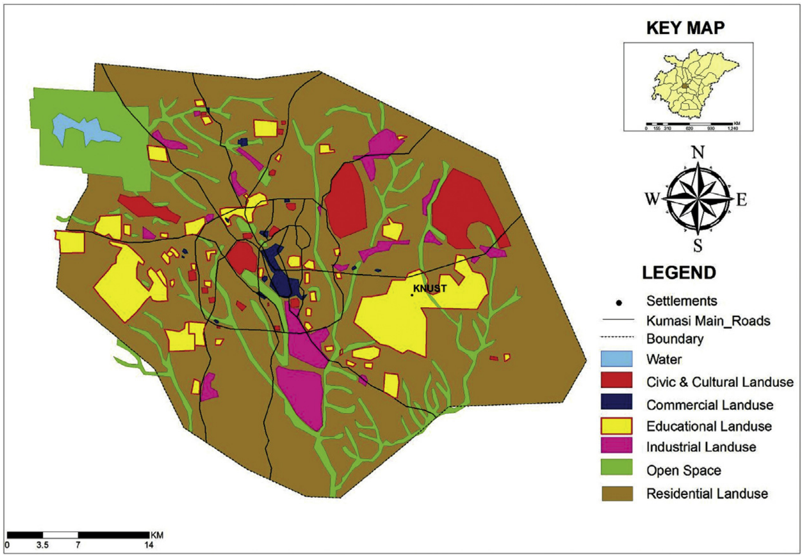

Fig. 3. Structure plan of the Kumasi Metropolitan Area.

sustain their jobs (73%), 2) to safeguard their health and that of consumers (41%) and 3) to obtain the public's total acceptance for their produce (53%). These reasons appear to be consistent with those of earlier studies that identified that two out of every three open space vegetable farmers in Accra have no intentions of leaving the job even if they were offered salaried jobs (Drechsel and Keraita, 2014; Obuobie et al., 2006). The main reason why almost 35% of

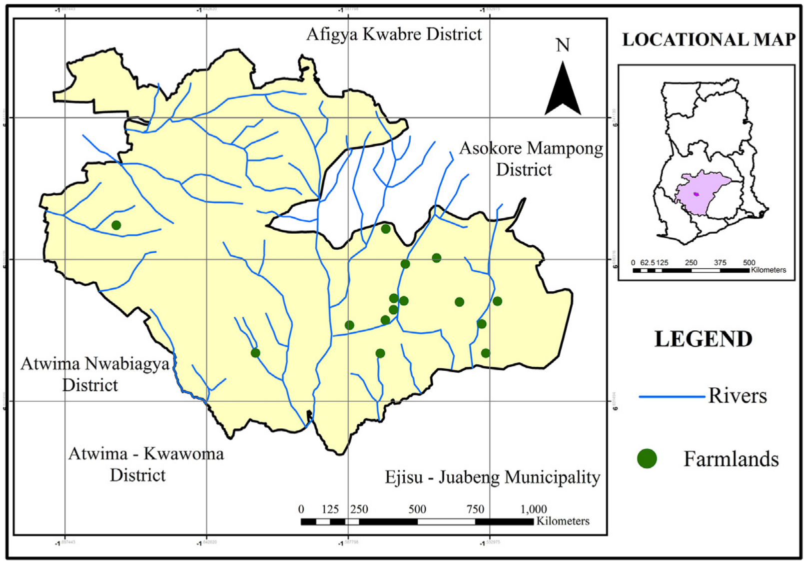

Fig. 4. Location of farmlands along surface water bodies.

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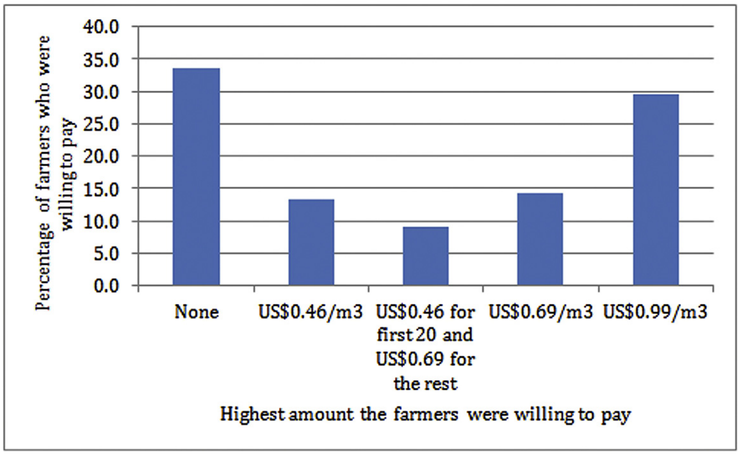

Fig. 5. Highest amount each open space commercial vegetable farmer was willing to pay for a cubic metre of reclaimed water.

the farmers were unwilling to pay was their perception that buying reclaimed water for irrigation would increase the cost of production while consumers may not be willing to pay more for their produce.

3.3.2. *Results of the focus group discussion with the vegetable farmers' associations*

All the four vegetable farmers' associations were willing to pay for reclaimed water for irrigation purposes. This is confirmation of the results obtained from the cross-sectional survey. The Farmwell Vegetable Growers' Association remarked that: "this is our occupation. So we are prepared to do everything within our means to protect it". The Progressive Vegetable Farmers' Association also opined that "our safety is paramount. So if reclamation will protect our health and that of our consumers in order to not be kicked out of our jobs, then we are willing to pay".

It emerged from the group discussions however that the conditions for willingness to pay were land tenure security and guaranteed/ready market for the produce. Land tenure security as a condition for farmers' willingness to invest is consistent with Henando de Soto's land titling ideology. de Soto argues that people will be willing to invest in their lands if they have security of tenure (Gilbert, 2002).

3.3.3. *Using 2 × 2 tables to identify the variables that could significantly explain the open space commercial vegetables farmers' willingness to pay for reclaimed water*

After scanning the 22 explanatory variables (refer to Table 2) with the Fisher's test, six of them had p-values ≤ 0.25 (Table 8). When these variables were

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Table 8. Stratification of the explanatory variables by using 2 × 2 table to identify the variables that explain with willingness to pay.

Variable	Willingness to Pay		Fisher's Exact Test (p-value)	OR	Confidence level		RR	Confidence level	
	Yes	No	2-sided						
1. Age									
Old	51	25	0.8	1.2	0.43	3.14	1.1	0.74	1.50
Young	14	8							
2. Sex									
Male	58	30	1.0	0.8	0.20	3.44	0.9	0.61	1.45
Female	7	3							
3. Household size									
Small	32	14	0.67	1.3	0.57	3.06	1.1	0.83	1.45
Large	33	19							
4. Educational level									
High	32	11	0.20	1.9	0.81	4.64	1.2	0.94	1.64
Low	33	22							
5. Consumption									
Yes	61	33	1.0	0.6	0.06	6.16	0.9	0.48	1.55
No	3*	1**							
6. Participation									
Yes	19	9	1.0	1.1	0.43	2.80	1.0	0.76	1.40
No	46	24							
7. Beds									
Small	33	15	0.83	1.2	0.51	2.67	1.1	0.79	1.40
High	32	18							
8. Membership									
Yes	16	13	0.16	0.50	0.21	1.23	0.8	0.54	1.12
No	49	20							

(*Continued*)

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Table 8. (*Continued*)

Variable	Willingness to Pay		Fisher's Exact Test (p-value)	OR	Confidence level		RR	Confidence level	
	Yes	No	2-sided						
9. Television									
Strong	60	25	0.03	3.8	1.14	12.89	1.8	0.91	3.70
Weak	5	8							
10. Radio									
Strong	48	22	0.49	1.4	0.57	3.51	1.1	0.81	1.58
Weak	17	11							
11. Experiences									
High	64	32	1.0	2.0	0.12	33.03	1.3	0.33	5.37
Low	1	1							
12. Land tenure									
Secure	5	4	0.48	0.60	0.15	2.42	0.8	0.45	1.51
Insecure	60	29							
13. Perception									
There are health risks	64	21	0.0	18.29	3.8	88.43	5.3	1.45	19.13
No health risks	1	12							
14. Agric extension service									
Yes	28	20	0.1	0.5	0.21	1.55	0.9	0.59	1.05
No	37	13							
15. Irrigation water quality									
Uncontaminated	0	0	0.35	0.0	Undefined		0.0	Undefined	
Contaminated	65	33							
16. Per capita income									
High	37	19	1.0	1.0	0.42	2.27	1.0	0.75	1.32
Low	28	14							

(*Continued*)

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Table 8. (*Continued*)

Variable	Willingness to Pay Yes	Willingness to Pay No	Fisher's Exact Test (p-value) 2-sided	OR	Confidence level		RR	Confidence level	
17. Net-revenue									
High	22	14	0.5	0.7	0.29	1.64	0.9	0.65	1.20
Low	43	19							
18. Farm size									
Relatively large	32	18	0.7	0.8	0.35	1.87	0.9	0.70	1.23
Relatively small	33	15							
19. Ability to pay US$0.46/$m^3$									
Yes	27	9	0.2	1.9	0.76	4.71	1.2	0.93	1.61
No	38	24							
20. Ability to pay US$0.69/$m^3$									
Yes	9	3	0.8	1.6	0.40	6.39	1.2	0.80	1.65
No	56	30							
21. Ability to pay US$0.99/$m^3$									
Yes	4	2	1.0	1.0	1.18	5.85	1.0	0.56	1.8
No	61	31							

The variable 'newspaper habit' was omitted because none of the farmers has the habit of reading newspapers.

* Was lowered by 1.

** Was increased by 1.

analysed further in a multivariable logistic regression using the backward elimination method, “perception" was the only one that could significantly explain (p-value = 0.01) the open space commercial vegetable farmers' willingness to pay for reclaimed water for irrigation (Table 9).

3.3.4. Using multivariable logistic regression to identify the variables that could significantly explain the farmers' willingness to pay

The results of the analysis of all the 22 explanatory variables provide a confirmation that "perception" was the only variable that could significantly explain (p-value = 0.01) open space commercial vegetable farmers' willing to pay for reclaimed water (Supplementary Table S1).

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Table 9. Multivariable analysis to identify the variables that significantly explain willingness to pay from the 2 × 2 table.

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1	Educational level	0.606	0.537	1.274	1	0.259	1.834	0.640	5.257
	Membership	-0.592	0.562	1.110	1	0.292	0.553	0.184	1.665
	TV habit	1.280	0.760	2.838	1	0.092	3.596	0.811	15.944
	Perception	3.650	1.114	10.734	1	0.001	38.475	4.334	341.576
	Agric extension service	-0.783	0.559	1.960	1	0.162	0.457	0.153	1.368
	ATP at US$0.46m^3	0.959	0.596	2.592	1	0.107	2.609	0.812	8.381
	Intercept	-3.629	1.383	6.886	1	0.009	0.027		
Step 2	Educational level	0.621	0.534	1.350	1	0.245	1.861	0.653	5.303
	TV habit	1.314	0.745	3.113	1	0.078	3.720	0.865	16.005
	Perception	3.579	1.107	10.454	1	0.001	35.829	4.093	313.613
	Agric extension service	-0.875	0.550	2.532	1	0.112	0.417	0.142	1.225
	ATP at US$0.46m^3	1.044	0.592	3.106	1	0.078	2.840	0.889	9.070
	Intercept	-3.764	1.364	7.614	1	0.006	0.023		
Step 3	TV habit	1.345	0.732	3.375	1	0.066	3.838	0.914	16.119
	Perception	3.638	1.109	10.757	1	0.001	38.017	4.323	334.330
	Agric extension service	-0.807	0.541	2.229	1	0.135	0.446	0.155	1.287
	ATP at US$0.46m^3	1.047	0.586	3.191	1	0.074	2.849	0.903	8.988
	Intercept	-3.619	1.355	7.135	1	0.008	0.027		
Step 4	TV habit	1.491	0.711	4.394	1	0.036	4.441	1.102	17.899
	Perception	3.707	1.102	11.317	1	0.001	40.737	4.699	353.189
	ATP at US$0.46m^3	0.834	0.564	2.188	1	0.139	2.303	0.763	6.955
	Intercept	-4.144	1.319	9.874	1	0.002	0.016		
Step 5	TV habit	1.342	0.681	3.879	1	0.049	3.827	1.007	14.553
	Perception	3.598	1.079	11.109	1	0.001	36.514	4.402	302.865
	Intercept	-3.629	1.219	8.861	1	0.003	0.027		
Step 6	Perception	3.599	1.071	11.299	1	0.001	36.571	4.484	298.260
	Intercept	-2.485	1.041	5.7	1	0.017	0.083		

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Table 10. Estimated annual gross revenue, total expenditure and net revenues.

Indicators	Annual Gross revenue (US$)	Total annual expenditure (US$)	Net annual revenue (US$)	Per capita annual net revenue (US$)
Minimum	640	27	427	93
25th percentile	1,975	185	1,607	482
50th Percentile	3,093	387	2,784	1,001
75th percentile	7,417	809	6,921	2,040
Maximum	26,667	3,803	25,051	17,483

3.3.5. Using cumulative odds ordinal logistic regression to identify the variables that could significantly explain the amount the farmers' were willing to pay

The results show that the odds of being willing to pay for reclaimed water was 123 times (95C.I. 7 to 2,030) higher if a farmer agreed that the current source of water for irrigation is harmful to his/her health. The model satisfies the proportional odds assumption (Chi-square = 181.79, df = 63 and p-value = 0.20). The Goodness-of-Fit test (Pearson Chi-square = 360.84, df = 367 and p-value = 0.58) also show that the model is adequate while the model-fitting-information (-2 Log Likelihood = 254.09, Chi-square = 38.36 and p-value = 0.01) implies that the model fits the data well. The Pseudo R-Square (Nagelkerke = 0.34) show that the model is able to explain 34% of the variance in the "amount farmers were willing to pay".

The result of the cumulative odds ordinal logistic regression is consistent with that of the Fisher's test and the logistic regression analyses. They show that the farmers who agreed that the water they used for irrigation posed some health risks to them and consumers are willing to pay for reclaimed water for irrigation purposes. The RR presented earlier in Table 8 therefore implies that farmers who agreed that the irrigation water was harmful were 5.3 times more likely to be willing to pay than that of those who did not.

3.4. Farmers' ability to pay for reclaimed water

3.4.1. Estimated annual gross revenue, total expenditure and net revenues

The results (Table 10) show that the median annual net-revenue was US $2,784.00 per annum and median annual per capita revenue was US$1,000. These have not been standardised according to the farm size. The per capita net revenue is higher than the upper poverty line of US$735 per annum per person used in Ghana. The result is also consistent with those of earlier studies that

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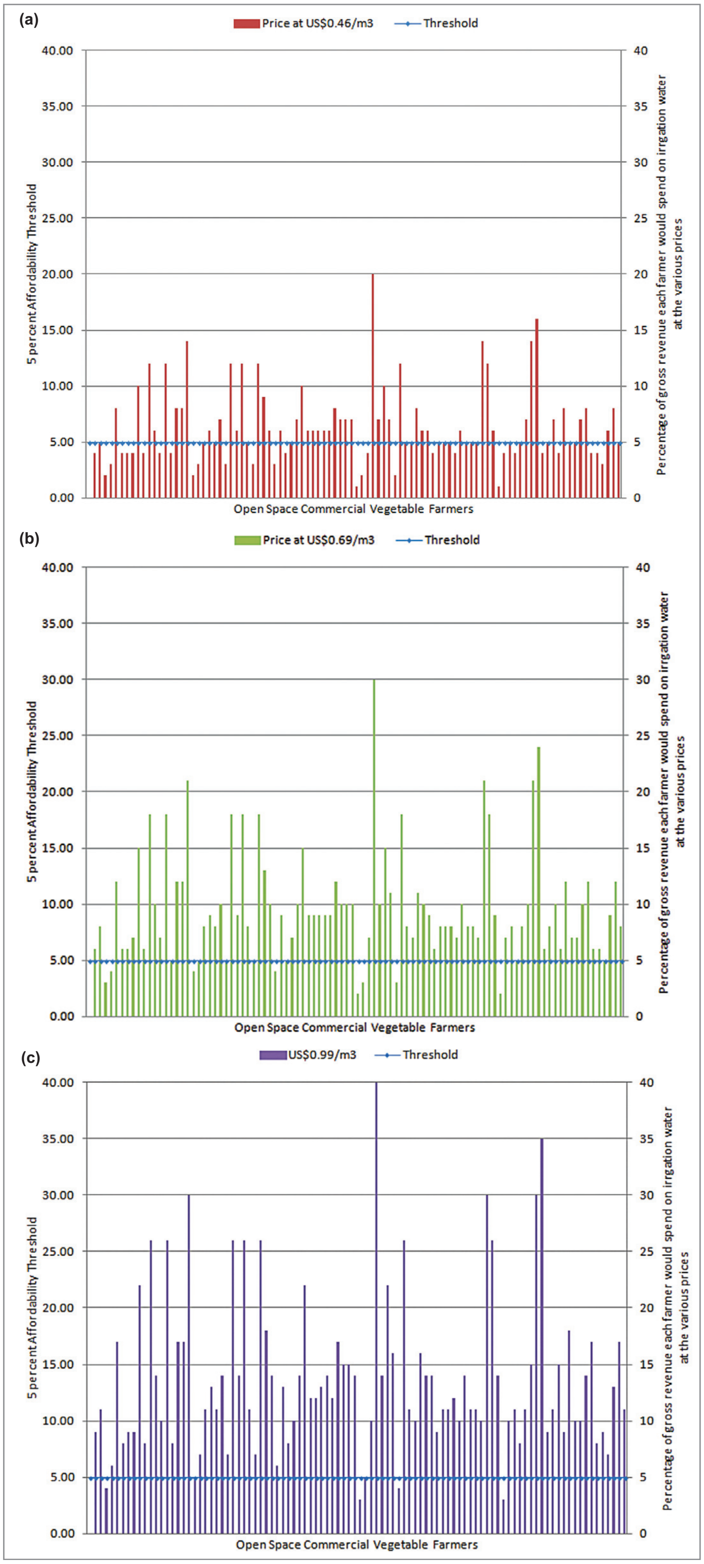

Fig. 6. Proportion of farmers' expenditure on irrigation water based on the assumed price of (a) US$0.46/m^3, (b) US$0.69/m^3, (c) US$0.99/m^3, plotted against the affordability threshold of 5 percent of gross revenue.

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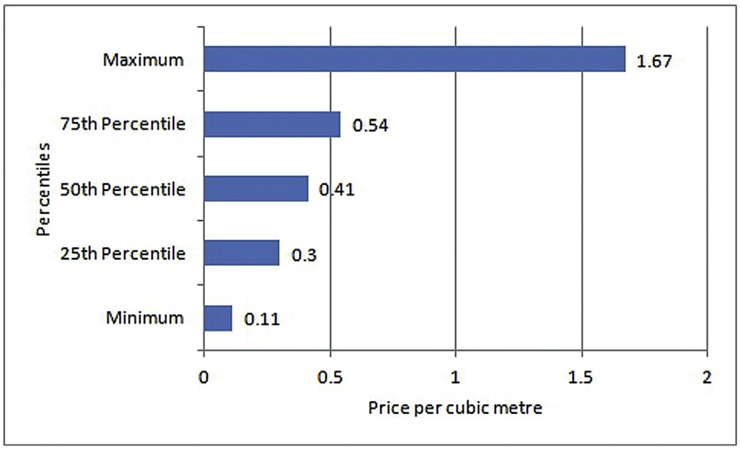

Fig. 7. Pricing reclaimed water based on the affordability threshold.

identified that urban open space commercial vegetable farmers' earnings were higher than the annual national incomes per capita in cities such as Nairobi in Kenya, Dakar in Senegal, Hyderabad in India and Guanajuato in Mexico (Ensink et al., 2004; Buechler and Devi, 2005; Scott et al., 2000; Drechsel et al., 2006).

3.4.2. *Ability to pay*

Analyses of the data revealed that the median annual volume of water used for irrigation by the farmers was 398 m^3 (minimum = 93 m^3, 25th percentile = 243 m^3, 75th percentile = 789 m^3 and maximum = 1,852 m^3). In this regard, the farmers' expected expenditure on reclaimed water will increase in line with the bid prices. The analysis shows that ability to pay is highest at US\$0.46/m^3 (Fig. 6a) but declines significantly when the prices were increased to US\$0.69/m^3 (Fig. 6b) and US\$0.99/m^3 (Fig. 6c). Only half (50%) of the sampled vegetable farmers would be capable of paying for reclaimed water if a volume was sold at US\$0.46. This then declined to 16% and 7% when the prices were increased to US\$0.69/m^3 and US\$0.99/m^3 respectively. The results suggest that none of the bid prices was affordable to all the open space commercial vegetable farmers covered in this study. In sum, despite their willingness to pay for reclaimed water for irrigation purposes, the analysis show that they could not afford if it would be priced based on the current treated water charges.

3.4.3. *Possible options that could be adopted to enhance the farmers' ability to pay*

Two options that could facilitate the farmers' ability to pay for reclaimed water have been assessed in this present study. They are: 1) adopting a price that is affordable to all the farmers or 2) reducing the volume of water used for irrigation.

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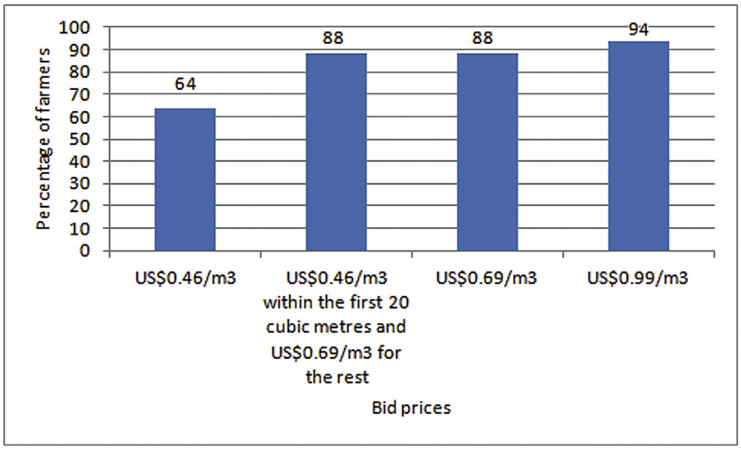

Fig. 8. Percentage of farmers who must reduce the quantity of water used for irrigation in order to afford the bid prices.

3.4.3.1. Adopting a price that is affordable to all the farmers

This requires that the amount each farmer would spend on reclaimed water should not exceed 5% of his/her annual gross revenue. It has been shown in Fig. 7 that a farmer who earned the least annual gross revenue (of US$640 per annum) would be capable of paying for reclaimed water at US$0.11/m^3 while the highest earner (US$26,667) could pay US$1.67/m^3. The affordable price is therefore US$0.11/m^3, which is higher than the price of reclaimed water (0.05 RMB [equivalent to US$0.008]) per m^3 in Beijing in China (Chang and Ma, 2012).

3.4.3.2. Reducing the quantity of water used for irrigation

The farmers would be capable of paying for reclaimed water at the various prices (US$0.46/m^3, US$0.69/m^3 and US$0.99/m^3) only if the quantity of water they used for irrigation in a year could be reduced. The levels of reduction range from 2–75 percent if a volume of reclaimed water would be sold at US$0.46/m^3. When the prices were adjusted to US$0.69/m^3 and US$0.99/m^3, the levels of reduction increased to 3–84 percent and 5–89 percent respectively. The proportion of farmers who would have to reduce the volume of water they used for irrigation was directly proportional to the bid prices (Fig. 8). This has implications for the adoption of water-use efficient technologies such as drip irrigation that is known to have about 90% field application efficiency (Brouwer et al., 1989; Gadanakis et al., 2015). The available drip kits in Ghana however do not support higher crop density (Amoah et al., 2011; Abaidoo et al., 2009). Farmers who decide to adopt drip irrigation would incur additional cost of US$141 for locally-manufactured drip kits (or US$211 if imported) for use on a typical farm size of 0.03 hectares

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(Amoah et al., 2011). The limited crop density, additional cost implications and land tenure insecurity could undermine the adoption of drip irrigation in open space commercial vegetable farming in Kumasi.

4. Conclusion

This paper provides evidence to show that open space commercial vegetable farmers in Kumasi were willing to pay for reclaimed water for irrigation purposes. It provides further evidence to show that farmers who agree that the water they use for irrigation is harmful to their health are more likely to be willing to pay for reclaimed water for irrigation. Willingness to pay is however conditioned by land tenure security. Pricing reclaimed water at US $0.11/m^3$ would be affordable to all the open space commercial vegetable farmers.

The results, although specific to the Kumasi, reflect the dynamics of low quality water reuse in many cities in low income countries. The conclusions may likely have significant policy implications not only for Kumasi but also the other cities in low income countries where the water reuse dynamics are similar.

4.1. Recommendations

We recommend that the Ministry of Food and Agriculture should use financial incentives combined with land tenure security to encourage farmers to use reclaimed water for irrigation. Reclaimed water could be priced at US$0.11/m^3$ whereas the lands along the surface water bodies could be zoned for crop farming purposes. The Ministries of Food and Agriculture, Local Government and Rural Development and Lands and Natural Resources should therefore collaborate to properly acquire these lands for open space commercial vegetable farming purposes. A buffer of between 10 to 20 meters radius from the streams should be maintained in order to protect the streams.

The farmers should be encouraged to use drip irrigation that can be combined with agronomic practices such as mulching. This implies that the Ministry of Food and Agriculture should facilitate the readjustments of the available drip kits in Ghana to make them suitable for use on higher density vegetable beds. The Ministry could facilitate the establishment of farmer field schools that can be used as media to sensitise the farmers on the health risks associated with the low quality water used for irrigation. This could encourage them to be willing to accept reclaimed water for irrigation purposes.

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Declarations

Author contribution statement

Owusu Amponsah, Håkan Vigre, Imoro Braimah, Torben Wilde Schou and Robert Clement Abaidoo: Conceived and designed the study; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Conflict of interest statement

The authors declare no conflict of interest.

Additional information

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